# Moscovian and Artinskian rocks in the frame of the cyclic Permo-Carboniferous deposits of the Carnic Alps and related areas

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**ABSTRACT**
Guidelines and legend for the Moscovian and Artinskian maps to be produced within the Peri-Tethys Programme are presented. An updated review of the most important composite sections exposed in different parts of the Carnic Alps and drilled in the northern Adriatic Sea is presented. The sections spanning a large part of the Mid-Late Carboniferous to terminal Permian time interval are correlated so as to show the major sedimentary cycles and the main regional trends of tectonic *vs* eustatic sea level changes. High frequency cyclicity is also summarized in terms of parasequences, especially for the Gzhelian stage, although the entire Pontebba Supergroup (Moscovian to Artinskian) was known for many decades as a classic cyclic sedimentation area.

**KEY WORDS**
Palaeogeographic maps, guidelines, legend, low and high frequency cycles, tectonics, eustatism, parasequences, Gzhelian, correlation, Southern Alps, Adriatic Sea.

**RÉSUMÉ**
Le schéma directeur et la légende des cartes du Moscovien et de l'Artinskien qui seront réalisées dans le cadre du Programme Péri-Téthys sont proposés. Nous présentons ici une révision des coupes composites les plus importantes des Alpes Carniques et des forages du nord de la Mer Adriatique. Les coupes, qui s'étalent sur une grande partie du Carbonifère moyen-supérieur au Permien terminal, sont corrélées et montrent les principaux cycles sédimentaires ainsi que les modifications tectono-eustatiques majeures. Une cyclicité haute fréquence est également résumée en termes de paraséquences, surtout au Gzhelien, bien que le Super-Groupe de Pontebba (Moscovien-Artinskien) soit connu depuis plusieurs décennies comme une région à sédimentation cyclique.

**MOTS CLÉS**
cartes paléogéographiques, directives, légende, cycles à faible et haute fréquence, tectonique, eustatisme, paraséquences, Gzhelien, corrélation, Alpes méridionales, mer Adriatique.

# FOREWORD

Before entering the topic of this paper, an introduction is needed to provide the aim, legend, and guidelines according to which the present and the following stratigraphic contributions (Pasini & Vai, Di Stefano & Gullo, Cassinis, Cassinis & Ronchi, Vai, Geluk, all in this volume) have been submitted to the *ad hoc* working group, in view of the compilation of the palaeogeographic maps of the Moscovian and Artinskian within the aims and the scope of the Peri-Tethys Programme (PTP). Further contributions are expected and welcome.

## GUIDELINES

The contributions provide original and/or updated stratigraphic rough data on the Moscovian and/or/to Artinskian time slices in the different areas within the scope of the PTP, mainly as spot columnar sections, with the aim to act as validation data points for the following map reconstruction:

**1.** The Moscovian Map, focusing the Age interval (about 312-305 Ma) and including additional information up to the top of the Carboniferous (about 296 Ma)

**2.** The Artinskian Map, focusing the Artinskian + Bolorian Age interval (about 280-273 Ma) and including additional information down to the base of the Permian (about 296 Ma).

The Moscovian Stage is used here as roughly represented by the *Aljutovella aljutovica* to *Fusulina cylindrica* fusulinid zones, by the *Idiognathoides marginodosus* to *Idiognathodus obliquus-Neognathodus roundyi* conodont zones, and by the *Paralegoceras* to *Wellerites* ammonoid zones.

The Artinskian + Bolorian Stages are used here as roughly corresponding to the *Chalaroschwagerina solita*, *Pamirina*, *Ch.* (="*Pseudofusulina*") *vulgaris*, *Misellina dyhrenfurthi* and *Misellina parvicostata* fusulinid zones, to the *Streptognathodus artinskiensis*, *Sweetognathus whitei*, *Neostreptognathodus pequopensis* and *N. leonovae* conodont zones, and are characterized by the new fusulinid genera *Mesoschubertella*, *Toriyamaia*, *Praeskinnerella*, *Darvasella* and by the ammonoid genera *Artinskia*, *Kargalites*, *Almites*, *Cardiella*, *Paragathiceras*, *Aristoceratoides*, *Pseudogastrioceras*. The selected late early Permian time has some advantages: it has a duration almost similar to that of the Moscovian; it is closely equivalent of the Chinese Chihsian and practically overlap with the Yachtash-Bolor faunal step of Leven (1993) comprised between the top of Sakmarian and the base of Kubergandian; it minimizes the imprecision deriving from the poor correlation and definition level of individual stages involved.

It is preferred to receive contributions coordinated in a set of sections by country or group of countries (such as *e.g.*: France, Belgium, UK, Germany, Poland, Hungary, Austria + Tchekia, Bulgaria + Rumania, former Yugoslavia, Turkey, Greece, Italy, Spain, NW Africa, Lybia, Central W Africa, Middle East + Arabia, Iran, Russia + Ukraina, Kazakhstan, a.s.o.). However, submissions provided by independent individuals or research groups are also welcome.

The contributions consist mainly of a set of *spot* columnar sections (stratigraphic columns), possibly correlated on a stratigraphic chart (see f.i. Ziegler 1988), possibly accompanied by location and/or simplified geological maps, and illustrated by a concise explanatory text. The text shall not exceed ten double-spaced typed pages (or five printed pages). Columnar sections, correlation charts (one or more if needed) and location/geological maps must be drawn on A4 sized sheets allowing final print reduction up to 50%. Each individual map drawing must contain a graphic scale.

Columnar sections are to be drawn and correlated on time/space (chronostratigraphic) diagrams. The thickness of the different lithostratigraphic units will appear from separate labelling in a side-column and from the text. The vertical axis of the columnar sections (time) will adopt the geological time scale shown in the next heading.

Each individual columnar section (representing a true spot-like section exposed in the field or drilled by a well, or a composite section whose

TABLE 1. — PTP time scale for the Carboniferous and Permian Periods (ages of the lower boundary in millions years).

| | | |
|---|---|---|
| **Early Triassic** | Induan | 251 Ma |
| | Changxingian | 255 |
| | Dhzulfian | 259 |
| | Midian | 264 |
| | Murgabian | 269 |
| **Late Permian** | Kubergandian | 273 |
| | Bolorian | 275 |
| | Artinskian | 280 |
| | Sakmarian | 288 |
| **Early Permian** | Asselian | 296 |
| | Gzhelian | 301 |
| **Late Carboniferous** | Kasimovian | 305 |
| | Moscovian | 312 |
| **Middle Carboniferous** | Bashkirian | 323 |
| | Serpukhovian | 328 |
| | Viséan | 345 |

elements are included within the resolution power of a point on a 1:10 000 000 scale map - which is about a circle of 1 km radius) should consist of a main column and a few side-colums. The main column should include lithology, lithostratigraphic units, and depositional environments. The side-columns should include data on thickness, unconformities, tectonic, magmatic and metamorphic events, tectofacies and other additional information (see legend). The location of each section within a resolution power of 1 km of radius should be identified by means of its Latitude and Longitude figures.

If graphically possible, the columns should include the data on both the Moscovian and the Artinskian (plus possibly the intervening interval) on the same sheet (also by using the long side of the A4 sheet).

Drawings should be submitted in both color and black and white (BW) versions, one for the sake of the future map compilation, the other for the immediate purpose of printing the volume. To speed work, it is suggested to label with number (see legend) the different units in the BW version and to fill them by hand colors for the color version.

The structure of the legend mainly conform to the previous one used in Dercourt *et al.* (1993) with some integrations derived from Ziegler (1988), Sassi & Zanferrari (1990) and Vai (1991). It seems particularly useful to include whenever possible in the maps the isopach contours or the margins of the main basins of the late Carboniferous (and Moscovian if available separately) and of the early Permian (plus Artinskian if available separately).

In the present stage, the basic legend type for both the stratigraphic columnar sections and the related geological maps (if available) is reported in Appendixes 2 and 3 respectively.

When additional subdivisions and symbols are needed, they have to be added by the contributors in their own legend sheets, preferably conforming to the use by the authors reported above.

PTP INTERVAL TIME SCALE

The numerical time scale for Carboniferous and Permian chronologic classification down to stage level tentatively adopted for the purposes of the PTP has a simple pragmatic meaning to enable a common frame for communication among different contributors. Howevet, as a matter of fact the present state of chronometric calibration of the conventional stratigraphic scale in the time interval concerned is largely unsatisfactory as appears from the very large error bars (from 3 to 9 Ma) affecting individual stage, series and system boundary ages (Odin 1994). Especially poor is the knowledge about the Dinantian or Mississippian subsystem. The late Carboniferous is mainly dated from continental successions not evenly related to the marine ones. A further limitation derives from the still poor level of formally defined standard chronostratigraphic subdivisions (GSSP) in this time interval. People involved are close to an agreement for the two system and some subsystem boundaries but have not yet paid any attention to the stage boundaries.

In such a condition, our aim was first to have a reliable frame of reasonable duration of stages, regardless of precise boundary ages, and second, to maintain a possible continuity with the time scale used in the previous Tethys Program.

Therefore, the numerical scale adopted here (Table 1) was based mainly on the time scale by

Ross *et al.* (1994), already used in Baud *et al.* (1993), as a preliminary output of the time scale by Menning (1995). Some modifications have been derived from Claoué-Long *et al.* (1995 and pers. comm.), Roberts *et al.* (1995) and from attempts at the best fit with Harland *et al.* (1990) and Odin (1994).

It is hoped that this first group of contriburions prompt other interested specialists to provide soon updated informations for those other countries which are relevant for the compilation of an accurate map reconstruction.

## LATE CARBONIFEROUS AND EARLY PERMIAN OF THE CARNIC ALPS

The late Moscovian to late Artinskian (*s.l.*) Pontebba Supergroup represents a classic area for late Palaeozoic stratigraphy acting as a bridge connecting the continental Permo-Carboniferous sequence of Western Europe and the marine one of the Russian Platform, the Urals and Middle East to Asia (peri-Tethyan and Tethyan realm). In fact, in the area including at least the Carnic Alps, the Karawanken, the outer Dinarides and the northern Adriatic Sea both facies interfinger conspicously, providing excellent tools for ecostratigraphic correlations (Kahler & Prey 1963; Selli 1963; Kochansky-Devidé 1965).
Within the frame of the eastern Southern Alps, the Pontebba Supergroup (Venturini *et al.* 1982) represents a superb exposure of a post Hercynian cover (episutural basin) sealing, with sharp angular unconformity, the severely thrusted Hercynian (Palaeocarnic) Chain and its shallow epimetamorphic equivalents of the Comelico basement (Vai 1976; Castellarin & Vai 1981; Vai & Cocozza 1986). The basal unconformity of the Pontebba Supergroup is well exposed over an area some hundreds of square km, although it is intersected by large Mesozoic extensional faults and Alpine thrust faults. Such faults are widely spaced from each other to enable large blocks showing the primary Hercynian basin/cover relationship preserved (Castellarin & Vai 1981). The western correlative of the Pontebba Supergroup is represented by the continental clastics of late Carboniferous (to Permian) age sealing the Southalpine crystalline basement in the Lombardy lake region, Orobic, Giudicarie and Alto Adige areas. Recent research on physical stratigraphy, environmental interpretation and palaeoclimatic evolution has provided the basis for a better understanding also in terms of sequence stratigraphy and sedimentary history (Venturini 1990, 1991; Krainer 1992).

### Cyclicity, sequences and trends in the Permo-Carboniferous Pontebba Supergroup (Figs 1-3)

Local autocyclic and tectonic processes as well as over-regional cycles have been recognized in the sedimentary patterns of the Pontebba Supergroup. Detailed descriptions and columnar sections showing the cycles are found in recent papers (*e.g.* Venturini 1990, 1991; and especially Massari *et al.* 1991), although cyclic sedimentation was also stressed by previous authors.
As a whole, the Pontebba Supergroup is viewed as a late Hercynian transtensional pull-apart basin-fill, consistent with both the post tectonic relaxation of the very short emersion of the Palaeocarnic Chain (Vai 1976) and the late Carboniferous-early Permian trans-Variscan megashear (Arthaud & Matte 1977). It forms a composite sedimentary cycle defined by the Hercynian (Carnic) non conformity at the base and the mid-Permian (Saalic) disconformity at the top. This sedimentary cycle is notably distinct from the Permo-Triassic cycle and following ones by its smaller extent and different architecture in response to a different stress regime.
The most prominent character of this Permo-Carboniferous sedimentary cycle is that it is composed by a quite regular series of cyclothems having a mean thickness of about 30 m. Almost the same type of modal cyclothem is recognized in two different sedimentary environments. One, dominated by marine carbonate deposits (Pizzul and Auernig Formations, see below), starts with an unconformity by which progradation and shallow-marine coarse silicoclastic deposits rest on ramp sediments; a transgressive fine-grained highly fossiliferous clastic layer is closed by a limestone horizon followed by shallowing upward clastic sediments. The other one, domi-

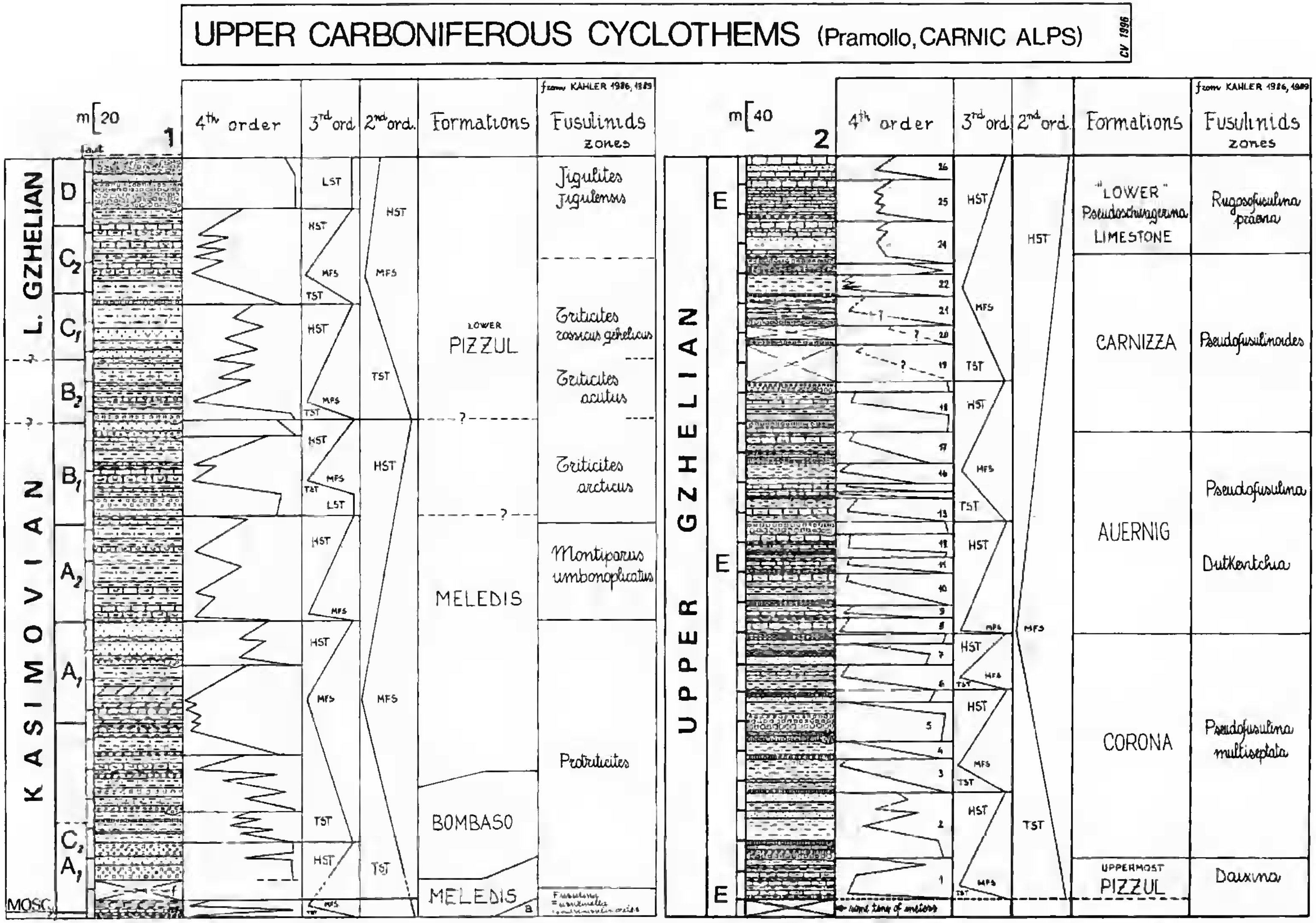



FIG. 1. — Third and fourth order lithocycles from the Carboniferous and earliest Permian of the Carnic Alps. Key: **LST-TST-HST**, low stand, transgressive and high stand systems tracts; **MFS**, maximum flooding surface; **B**, Bombaso Formation; the second column from left shows the stratigraphic subdivision according to the Austrian authors. Notice scale change from part 1 to part 2 of the section. See also legends in Appendixes 1, 2 and 3.

nated by more or less continental silicoclastics (Corona and Carnizza Formations), starts with superimposition of fluvial conglomerates on deltaic to coastal plain muddy sediments followed by fine-grained transgressive clastic ramp deposits and highstand fine silicoclastic marine bands. It follows that the upper Carboniferous cyclothems of the Carnic Alps can be described as high-frequency small-scale sequences in terms of sequence stratigraphy and depositional systems. Furthermore, the alternation of either carbonate or silicoclastic bundles suggests a climatic modulation of higher rank cyclicity in respect to that involved in the generation of cyclothems.

A similar, although more irregular and less studied cyclicity, is shown in almost all remaining late Carboniferous to early Permian Formations except the Trogkofel Limestone (and related units, see below).

Both larger and smaller-scale cycles recognized in the Pontebba Supergroup are closely similar to the classical Permo-Carboniferous cyclothems of North America, the Russian Platform, Western Europe and Africa (or to their internal subdivisions in formations and members). As an example, one can compare the impressive correspondence between the four Gzhelian formations of the Carnic Alps (Pizzul, Corona, Auernig and Carnizza) and the corresponding four Gzhelian "horizons" of the Russian Platform (Ross & Ross 1988: 234; Izart *et al.* 1995). On the other hand, similarly impressive is the almost perfect match between twenty-six cyclothems of the upper Gzhelian in the Carnic Alps (Fig. 1) and the twenty-one units of the roughly corresponding Virgilian in Kansas (Ross & Ross 1988: 233). The twenty-two cycles recognized within the Corona, Auernig and Carnizza Formations (Massari *et al.* 1991) added to the three out of the four cycles known in the "Lower" Pseudoschwagerina Formation (Homann 1969) altogether roughly correspond to the upper half of the Gzhelian, lasting as a whole stage about 5 Ma The ratio closely approximates the magic figure of 100 ka, which is thought to be the forcing orbital (short excentricity) factor of many depositional cycles (*e.g.* the glacial Pleistocene climatic-controlled paired Emiliani isotope "stages").

The cyclostratigraphic analysis of the Upper Carboniferous succession of the Pramollo Basin ("Auernig group" and its basal immature clastics, referred to as Bombaso Formation) deserves some additional remarks.

**1.** The Bombaso Formation is heteropic with both the Meledis Formation and the lower part of the Pizzul Formation (Venturini 1990, 1991). This is an effect of the Kasimovian synsedimentary tectonics, resulting in the uplift of a narrow Horst exposed to erosion. It lined up with the basin axis splitting it into two separated and independent Graben.

**2.** During late Gzhelian times the north-eastern Grabe, that is the well known area of Auernig, Carnizza and Corona Montains, was affected by strong tectonic subsidence. The sedimentation rate remarkably increased as compared to the previous Kasimovian-early Gzhelian figures (Venturini 1991).

It follows that, for a correct analysis of the cyclic upper Gzhelian succession, interfering of possible tectonic pulses must be carefully discounted from the effects of the glacio-eustatic oscillations.

## The Permo-Carboniferous Pontebba Supergroup (Fig. 2)

For a better understanding of the palaeogeographic meaning of the Moscovian and Artinskian rocks exposed in the Carnic Alps, a summary about its almost continuous succession ranging from late Moscovian to early Kubergandian (in the eastern area) is useful.

The sequence starts with the fine clastic to carbonate mainly basinal Meledis Formation not conformably overlaying the Hercynian chain. The Meledis Formation often rests on a thin basal carbonate breccia body (Malinfier Horizon) and in some areas is laterally replaced by fault-scarp related plygenic breccias and immature coarse-grained siliciclastics (Pramollo Mb) named, as a whole, Bombaso Formation (Venturini 1990). The Meledîs and Bombaso Formations span from the late Moscovian (Mjackovian) to the Kasimovian (*Protriticites* to *Montiparus* Zones). They are followed by the late Kasimovian to early Gzhelian (*Triticites, Jigulites* and *Daixina* Zones) Pizzul Formation, composed of outer shelf limestones and pelites alternating

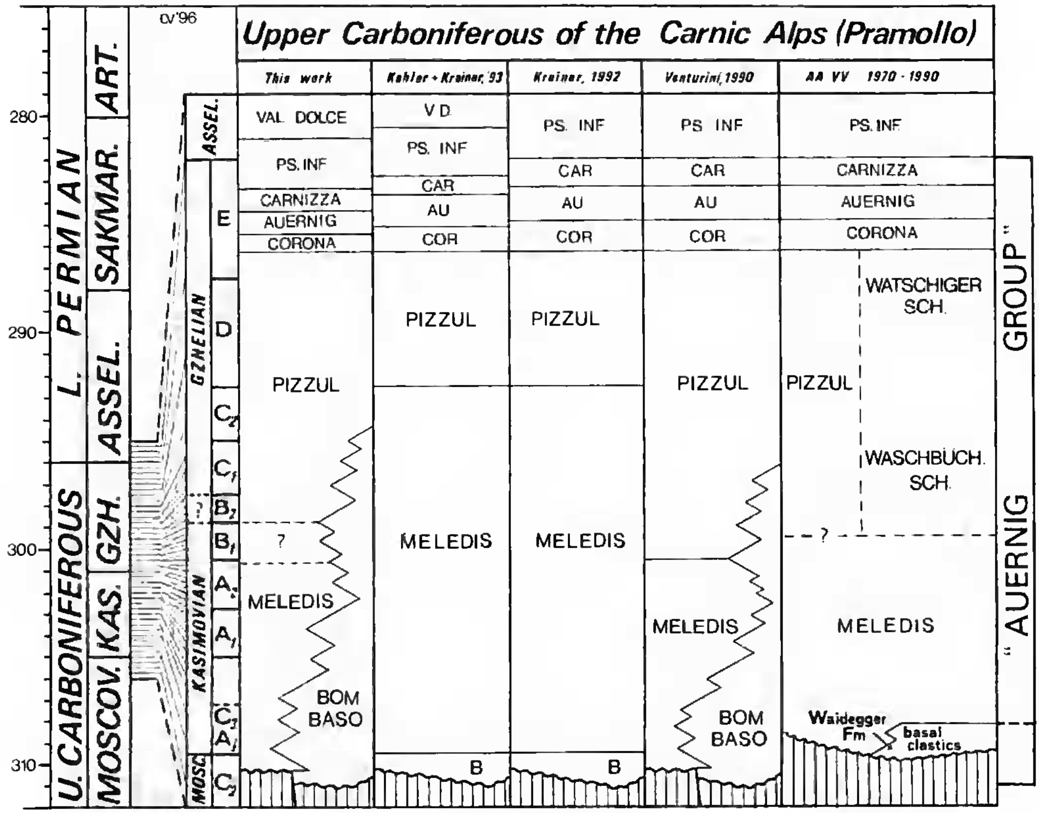



FIG. 2. — Lithostratigraphic subdivision of the Upper Carboniferous of the Carnic Alps. Key: **AU**, Auernig Fm; **B**, Bombaso Formation; **Cor**, Corona Formation; **PS. INF.**, "Lower Pseudoschwagerina" Formation; **V.D.**, Val Dolce Formation; the fifth column from left shows the stratigraphic subdivision according to the Austrian authors. See also legend in Appendixes 1, 2 and 3.

with coastal-deltaic coarse-grained clastics.

The Corona Formation of late Gzhelian (*Daixina* and *Pseudofusulina-Rugosofusulina* Zones) follows with fine-grained open shelf pelites (and a single limestone layer in the distal area) alternating with alluvial plain to deltaic conglomerates and sandstones (including some thin coal seems). The drastic decrease in carbonate productivity, without major change in physiographic conditions of the basin, suggest a marked temperate to cool climatic oscillation. This formation is characterized by 30 to 40 m thick cyclothems (parasequences).

The following Auernig Formation, of late Gzhelian age (*Pseudofusulina-Rugosofusulina* Zones) is composed by outer shelf marine carbonates and pelites alternating with coastal-deltaic coarse-grained clastics. This formation is characterized by cyclothems (parasequences) of mean thickness of about 20 m (range 15 to 40 m).

The Carnizza Formation closes the late Gzhelian (*Pseudofusulina-Rugosofusulina* Zones) and is made by outer shelf pelites and subordinate limestones alternating with coarse-grained sandstones and quartz conglomerates of deltaic environment.

The "Lower" Pseudoschwagerina Formation of latest Gzhelian to Asselian age (*Schwagerina* Zone) is composed of massive to bedded shallow-water limestones interlayered by fine-grained marine silicoclastic sediments. Four cyclothems have been recognized (Homann 1969) and recently analysed (Samankassou 1995). The Val Dolce Formation of Asselian age (*Schwagerina*

Zone) is dominated by terrigenous deposits with minor limestone intercalations (like in most of the late Carboniferous) representing delta to prodelta sequences.

Traditionally, the Carboniferous/Permian boundary was placed between the Carnizza and the "Lower" Pseudoschwagerina Formations. More recently a position inside the "Lower" Pseudoschwagerina Formation at the base of the *Occidentoschwagerina alpina* Zone was suggested (Kahler & Krainer 1993). Lately, Davydov & Kozur (1995) have proposed an even higher place at the base of the Val Dolce Formation (Grenzlandbänke). Waiting for further taxonomic precision we adopt here a boundary place still within the "Lower" Pseudoschwagerina Formation inside the not yet investigated interval above sample SK115 of Kahler & Krainer (1993).

The "Upper" Pseudoschwagerina Formation of late Asselian to early Sakmarian age (*Zellia* Zone; Forke 1995) is composed of alternating massive reefal and bedded partly marly inner shelf limestones.

The following Trogkofel Limestone (Sakmarian, *Robustoschwagerina* and *Pseudoschwagerina* Zones) and the following related Tressdorfer Limestone (early Artinskian, *Pamirina* Zone) and Coccau (= Goggau) Limestone (mid to late Artinskian, *Misellina* Zone) represent as a whole a reef-complex of shelf and shelf-edge environment, which has been compared with the Capitan Reef of Texas (Flügel 1981).

THE MOSCOVIAN OF THE CARNIC ALPS (Fig. 3)

Only the late Mjackovian substage of the Moscovian is certainly represented in the early lithostratigraphic units not conformably overlying the severely folded and thrusted Palaeocarnic Chain. The lowermost fusulinids found above the unconformity are representative of the *Protriticites* Zone and include *Eostaffella*, *Paraendothyra*, crinoids, brachiopods, echinoids, molluscs, bryozoans, trilobites and phylloid plus dasycladacean algae (Kahler & Prey 1963; Selli 1963; Pasini 1963, 1974; Vai *et al.* 1980; Venturini 1990). The stratigraphic units bearing this fauna are the Malinfier Horizon (matrix), the Meledis Formation and its lateral equivalent Pramollo Mb (matrix) which have been referred to above. Consistent with the above dating are also macrofloral and palynomorph data. In fact, ferns (*Neuropteris* ex gr. *ovata = grand'euryi*) of Cantabrian age (late Moscovian to early Kasimovian) occur at the top of the Meledis Formation (Vai *et al.* 1980). Also the palynomorphs of the lowermost Bombaso Formation (Francavilla 1966), dated at the Westfalian B or so (early Moscovian), are consistent with the age of the first fusulinids. It suggests also a possible earlier Moscovian onset of the post-tectonic sedimentation of the Pontebba Supergroup.

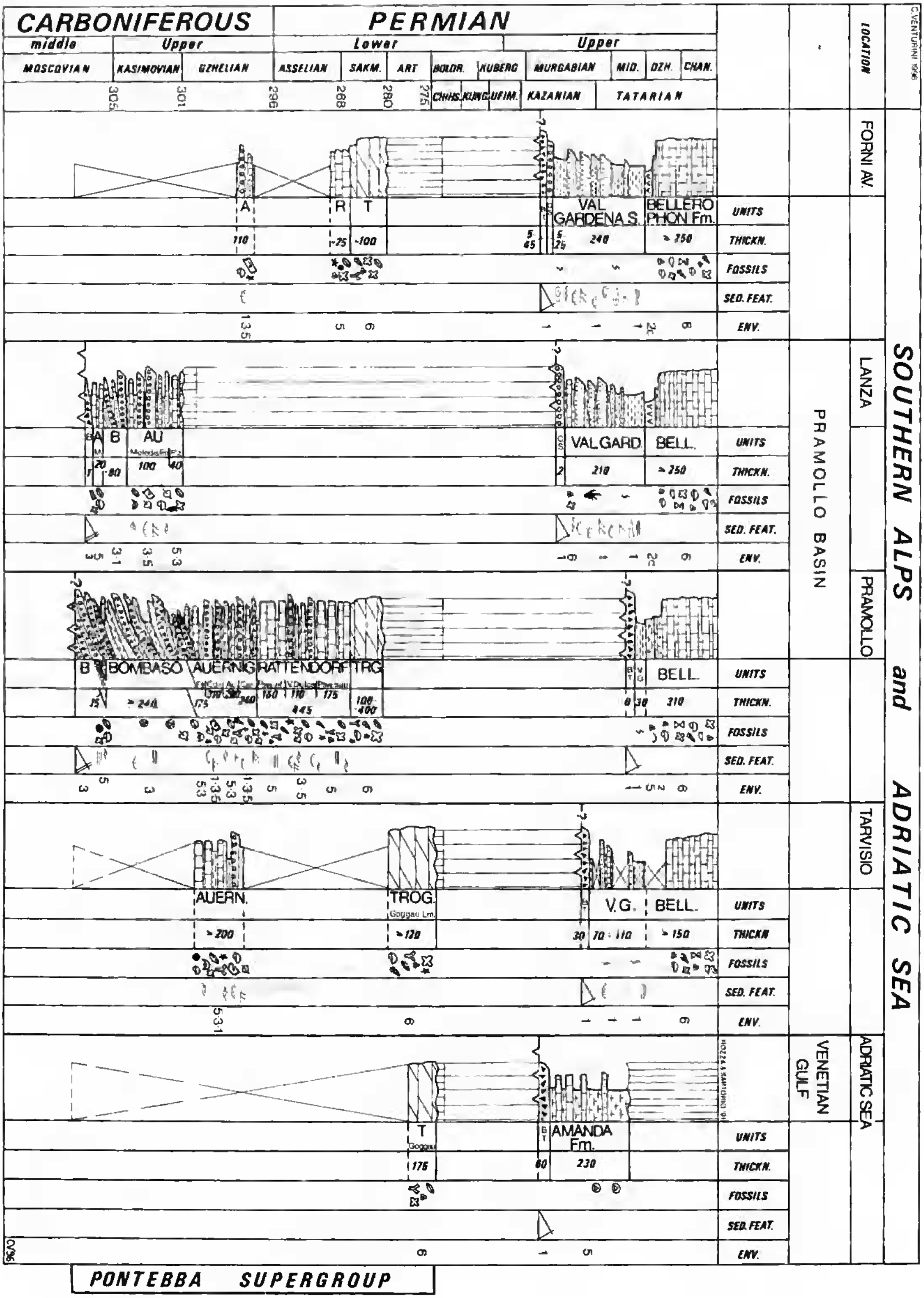
The major faunal affinities are found between Carnic Alps, the Dinarides and the Russian Platform to Urals. Floral relationships are more close with the Cantabrian region than with NW Europe. Recent finding of Kasimovian conodonts suggests close affinity with Chinese elements (Perri & Spalletta, pers. comm.; see also Forke 1995).

THE ARTINSKIAN OF THE CARNIC ALPS (Fig. 3)

On top of the 150 to 400 m thick Trogkofel Limestone (a complex system of *Tubiphytes* buildups) of Sakmarian age, in places of the "middle" Permian reef-complex, some limestone masses escaped the Saalic uplift and erosion, showing remnants of the Artinskian stage *l.s.*

The lower Artinskian is represented directly by the Tressdorfer Limestone (15 m thick). It is made of mainly brecciated shallow-water limestone with both extraformational (reworked from the underlying Trogkofel and "Upper" Pseudoschwagerina Formation) and autochthonous components rich in *Mizzia*, other algae, gastropods, fusulinids, other foraminifera, pelmatozoans and bryozoans. It contains sometimes *Praeparafusulina lutugini* which is an element of the Russian *Pseudofusulina lutugini* Zone. A quite

FIG. 3. — Stratigraphic correlation of the main Moscovian to Artinskian columnar sections of the southern Alps (exposures) and the Adriatic Sea (subsurface) and their interpretation (chronometric calibration of the chronostratigraphic scale conforms to that discussed in the first part of the paper). Key: **A**, Auernig; **B**, Bombaso; **B.T.**, Tarvisio Breccia; **C.S.**, Sesto Conglomerate; **M**, Meledis; **Piz**, Pizzul; **T-TROG**, Trogkofel; **R**, Rattendorf; **V.G.**, Val Gardena; **Bell.**, Bellerophon. See legend in Appendixes 1, 2 and 3 for other symbols.


CARBONIFEROUS
PERMIAN
middle
Upper
Lower
Upper
MOSCOVIAN
KASIMOVIAN
GZHELIAN
ASSELIAN
SAKM.
ART
BOLOR.
KUBERG
MURGABIAN
MID.
DZH.
CHAN.
CHIHS.
KUNG.
UFIM.
KAZANIAN
TATARIAN
305
301
296
268
280
275
LOCATION
C.VENTURINI 1996
FORNI AV.
LANZA
PRAMOLLO
TARVISIO
ADRIATIC SEA
PRAMOLLO BASIN
VENETIAN GULF
SOUTHERN ALPS and ADRIATIC SEA
UNITS
THICKN.
FOSSILS
SED. FEAT.
ENV.
VAL GARDENA S.
BELLERO PHON Fm.
VALGARD.
BELL.
BOMBASO
AUERNIG
RATTENDORF
TRG
AUERN.
TROG.
Goggau Lm.
V.G.
AMANDA Fm.
PONTEBBA SUPERGROUP

effective pre-late Kubergandian erosion is suggested by the frequent occurrence of Tressdorfer- and Trogkofel Limestone blocks in the late Kubergandian to Murgabian Tarvisio Breccia (Fig. 3).

The upper Artinskian is represented by the Coccau Limestone. This is a light grey massive shallow-water limestone quite similar to the previous two formations. In its upper part a rich fusulinid fauna from the *Pseudofusulina vulgaris* Zone, including *Pamirina darvasica*, *Minojaponella elongata* and *Nagatoella* aff. *orientis* is found, suggesting an age from Artinskian to early Bolorian or early Kungurian, at the very base of the *Misellina* Zone (Kahler 1992).

## The Artinskian of the northern Adriatic Sea (Fig. 3)

The age assigned to the Coccau Limestone above was confirmed recently from the Amanda 1 well drilled by AGIP about 50 km E of Venice (45°24'47"N - 13°00'38"E). The Permian, beneath the mid Triassic Latemar Formation (late Anisian-Ladinian), was encountered from 6840 to 7305 m depth (Sartorio & Rozza 1991). It is represented from the top by:

**1.** The Amanda Formation, dark to reddish marls, clay, silty sandstones with palynomorphs, some carbonate intercalations with fusulinids (*Kahlerina pachytheca* of the *Neoschwagerina* Zone), foraminifera and algae (*Tubiphytes*) and fine breccias representing the late Permian (possibly late Kubergandian to Murgabian).

**2.** The Tarvisio Breccia, composed of reworked clasts from the underlying Coccau (= Goggau) Limestone and a red clayey matrix, deposited in a subaerial environment.

**3.** The 175 m thick Coccau Limestone, represented here mainly by shallow-water platform rudstone and grainstone facies, including rich fusulinid fauna (*Pseudofusulina, Praeparafusulina, Acervoschwagerina, Misellina*), foraminifera, algae (*Tubiphytes, Archaeolithoporella*), bryozoans, brachiopods, pelmatozoans, bivalves, ostracods and rare *Bellerophon*. The core taken from the middle part of the formation was assigned to the *Misellina claudiae* Zone of the latest early Permian (Chihsianskian or equivalents).

## Final remarks

The correlation chart in figure 3 shows two major stratigraphic cycles easily traced along the entire western Adriatic and eastern Southalpine areas. The first one, represented by the Pontebba Supergroup, starts with the late Moscovian and lasts at least up to the entire Artinskian and part of the Bolorian. It is mainly marine, with continental clastic supply strongly decreasing upwards and dominated by western provenance. Thalassocratic conditions culminate with the early Permian, especially Sakmarian to Artinskian. It is followed by a remarkable, general although differential uplift and erosion, occurring sometimes during the late Bolorian to Kubergandian interval. How much the relative uplift is to be related to a concurrent eustatic sea level drop could be argued only upon establishment of more reliable sea level curves for the Permian. The second cycle begins with the early Murgabian spanning the Permo-Triassic boundary, except for the Venetian Gulf area showing late Permian/early Triassic uplift. This is a broadly transgressive cycle dominated by the flood plain Val Gardena Formation evolving to the Bellerophon sebkhas and shelf. This trend is quite contrasting with the more common worldwide Permian regression.

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## Appendix 1: Key to fossil and sedimentary structure symbols

**FOSSILS**

- Acritarchs, Chitinozoa
- Algae
- Ammonoids, Nautiloids
- Amphibians
- Bivalves
- Brachiopods
- Brachiopod spine
- Bryozoans
- Charophytes
- Conchostracans
- Conodonts
- Corals
- Crinoids
- Echinoderms
- Fishes
- Fish teeth
- Foraminifera (benthic)
- Foraminifera (planktic)
- Foraminifera (indet.)
- Fusulinids
- Gastropods
- Graptolites
- Insects
- Nannofossils
- Orthocones
- Ostracodes
- Palynoflora
- Plantae (wood)
- Plantae (leaves)
- Radiolarians
- Reptiles
- Sponges
- Sponge spicules
- Stromatoporoids
- Tetrapod foot prints
- Trilobites
- Vertebrate teeth
- Vertebrate bones
- Shells indet.
- Bioclasts indet.

**SEDIMENTARY STRUCTURES**

- Bioturbation
- Large scale cross bedding
- Small scale cross bedding (r: ripple)
- Parallel bedding
- Lamination
- Channel
- Slump
- Tempestite

# Appendix 2: Columnar section legend

## MAIN COLUMN
## DEPOSITIONAL ENVIRONMENT

- 1 — Continental, Lacustrine (orange)
- 2 — Evaporites (pink)
- 3 — Deltaic (pale yellow)
- 4-5 — Shallow marine clastics (green)
- 9 — Deep marine clastics (blue)
- 10 — Deeper marine clastics (brown)
- 6 — Shallow carbonates (gold yellow)
- 7 — Pelagic rise (olive green)
- 8 — Deep carbonates (light blue)
- Erosional hiatus
- Non-depositional hiatus
- Lack of data

## LITHOLOGY

- Breccia
- Sand, conglomerate
- Sand
- Sand, silt, shale
- Carbonate, sand
- Carbonate (p=packstone, g=grainstone, w=wackestone, m=mudstone)
- Reefal carbonate, bindstone
- Carbonate, shale
- Pelagic carbonate
- Nodular carbonate
- Shale, some carbonate
- Shale
- Turbidites (s=silicoclastic, v=volcanoclastic, c=carbonate)
- Organic shale
- Dolomite
- Sulphate
- Halite
- Coal
- Chert, radiolarite
- Volcanics
- Volcanoclastic deposits
- Concretion (Fe: iron, etc.)
- O — Oolite
- P — Phosphate
- B — Bauxite
- Pa — Paleosol
- ● — Oil, gas

## SIDE-COLUMN

- Erosion, unconformity
- Low / High angle unconformity
- R W — Rift / Wrench induced
- I F — Inversion, folding
- TR RE — Transgression, regression
- U C — Regional uplift / collapse
- M ★ ✚ — Metamorphic, volcanics, intrusives

## APPENDIX 3: MAP LEGEND

### DEPOSITIONAL ENVIRONMENT AND MAIN LITHOLOGY

| | |
|---|---|
| 1 | Mainly continental clastics orange (c=coarse; f=fine; l=lacustrine, d=desertic, lateritic) |
| 2 | Evaporites pink (t=and clastics; c=and carbonates) |
| 3 | Deltaic shallow marine, mainly sands pale yellow |
| 4 | Shallow marine, mainly shales pale green |
| 5 | Shallow marine, carbonates and clastics green |
| 6 | Shallow marine, mainly carbonates gold yellow |
| 7 | Pelagic rise olive green |
| 8 | Deeper marine carbonates light blue |
| 9 | Deeper marine clastics blue |
| 10 | Deeper marine, mainly sands (turbidites) light brown |
| 11 | Basins floored by oceanic lithosphere dark blue |

### TECTONIC SETTING AND LITHOSPHERIC TYPE

| | | |
|---|---|---|
| 12 | Foreland | Normal lithosphere |
| | Foredeep basin | Normal lithosphere |
| 14 | Active fold belt | Thick lithosphere |
| 13 | Inactive fold belt | Normal lithosphere |
| 12 | Anorogenic craton | Normal lithosphere |
| | Rift | Thin lithosphere |
| 11 | Oceanic lithosphere dark blue | |

### VOLCANIC ACTIVITY

| | |
|---|---|
| 15 | Basaltic plateau dark red |
| 16 | Porphyric plateau light red |
| ★ | Anorogenic |
| ☆ | Orogenic |

### AUXILIARY SYMBOLS

- Fault, wrench, normal
- Major thrust fault 1 active, 2 inactive
- B and A subduction 1 active, 2 inactive
- Accretion wedge
- Major anticlinal axis
- Isopach of the ..... (stage)
- Basin margin
- Direction of clastic influx
- Limit of palaeoenvironment
- Continental slope
- Active sea-floor spreading axis and transform fault
- As above, with magnetic anomaly